

# **FRED Reports**

SOCKEYE SALMON SMOLT STUDIES  
KASILOF RIVER, ALASKA 1984

by  
Loren B. Flagg,  
Patrick Shields,  
and David C. Waite  
Number 47



**Alaska Department of Fish & Game**  
Division of Fisheries Rehabilitation,  
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May 1985

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## ABSTRACT

The estimated number of sockeye salmon, *Oncorhynchus nerka*, smolts emigrating from Tustumena Lake in 1984 was 14.3 million. Of these, 11.4 million (80%) were age 1.0 and 2.9 million (20%) age 2.0. The estimated sockeye salmon smolt biomass produced from the lake was  $51.6 \times 10^3$  kg.

The weighted mean lengths, weights, and ages of migrating sockeye salmon smolts were determined from randomly selected samples. The mean length of age 1.0 smolts was 72.7 mm and the mean weight was 3.3 g. Age 2.0 smolts averaged 84.5 mm in length and 5.2 g in weight.

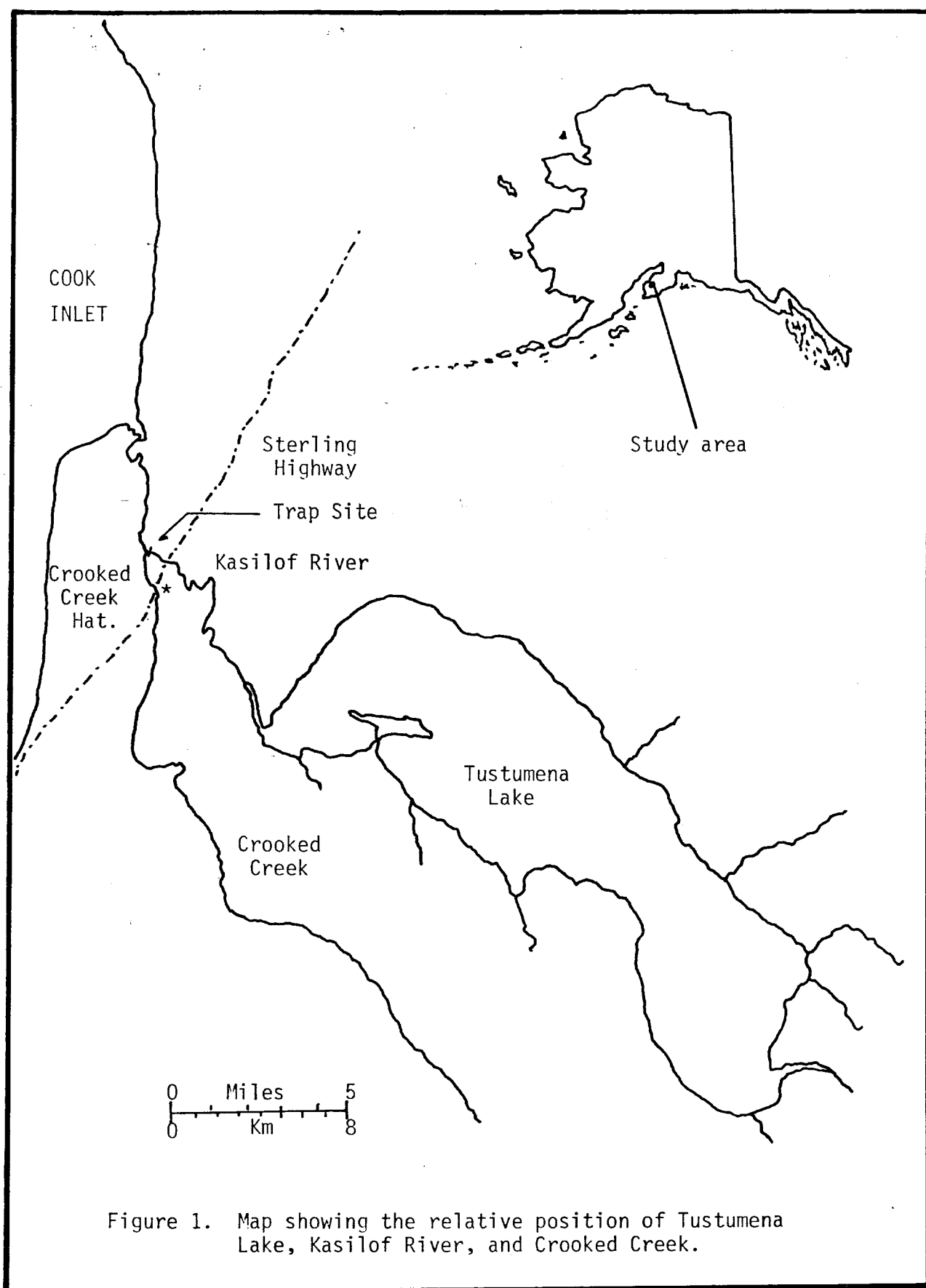
Sockeye salmon smolts captured in the Kasilof River were examined for missing ventral fins, which represented hatchery-released fish. During the migration, 68,539 smolts were examined and 378 marked fish were recovered. The estimated survival rate of marked hatchery fry to age 1.0 smolt was 16.3%. The estimated hatchery contribution to the total smolt outmigration was 3.15 million or 22.1%.

Key Words: sockeye salmon smolt, *Oncorhynchus nerka*, Tustumena Lake, Kasilof River, fan traps, migration estimate, mark and recapture, fin-clipped fish, survival rate, and hatchery contribution.

## INTRODUCTION

Studies have been conducted on the Kasilof River since 1980 to obtain information on the sockeye salmon, *Oncorhynchus nerka*, smolt emigration from Tustumena Lake and to assess the survival and contribution of hatchery stocked sockeye salmon fry to the total outmigration (Todd 1981; Flagg 1982; Flagg, Owecke, and Waite 1984). Hatchery-raised sockeye salmon fingerling have been released into Tustumena Lake every year since 1976, except for 1977 (Appendix Table 1). The stocking was performed by the Fisheries Rehabilitation, Enhancement, and Development Division (FRED) of the Alaska Department of Fish and Game (ADF&G) in an attempt to enhance sockeye salmon production in the system. This report presents the results of the 1984 smolt project.

The smolt study site is located on the Kasilof River approximately 7 km upstream from Cook Inlet and 10 m upstream from the confluence of Crooked Creek and the Kasilof River (Figure 1). The Kasilof River drains Tustumena Lake, which is turbid with glacial flour. It is an important sockeye salmon nursery lake with a surface area of 29,100 ha. The average estimated adult sockeye salmon return per year (catch plus escapement) attributed to Tustumena Lake wild stocks was 542,000 from 1975-1983 (Tarbox 1984). Average escapement to the lake during this period was 161,000 (King et al. 1984).



The objectives of this project were as follows:

1. to determine the timing and magnitude of the sockeye salmon outmigration;
2. to assess the survival rate of hatchery-reared sockeye salmon fingerling and their contribution to the total smolt migration; and
3. to determine the age structure and the average weight and length of the migrating smolts.

#### MATERIALS AND METHODS

##### Fan-Trap and Live-Box Design

Canadian fan-traps were used to capture smolts and to monitor their migration. The fan-traps were constructed of angle aluminum, so they were light enough to transport yet strong enough to withstand the current and the impact from large debris. The traps are 1.5-m square at the upstream opening and 3 m in length. From the mouth, they taper to a 0.3-m-square opening.

The traps were attached to a cable that was secured to large boulders in the river. The traps were further anchored by 20-mm steel reinforcing rods driven into the riverbed through eyelets on the bottom front edge of the traps. Aluminum tripods equipped with a pully system were used to adjust the height of the downstream end of the traps. Elevation adjustments were made to accommodate different water levels to prevent the downstream trap end from becoming submerged.

Holding boxes were connected to the downstream trap end by a camlock fitting. The live-boxes were rectangular with dimensions of 1.5 x 0.9 x 0.6 m. The front, back, and bottom were constructed of 3/4-inch plywood and the remaining two sides of perforated aluminum plate. These boxes were floated by attaching styrofoam panels to both sides. The bottom was vented to provide continual water circulation. Illustrations of these traps and live-boxes appear in previous reports (Flagg et al. 1984).

#### Smolt Sampling and Enumeration

One trap was placed in the river on 11 May to monitor for early migrants. Two traps were added on 15 May, and on 16 May a fourth trap was installed. The traps were fished until 9 July for a total time of 60 days. Weights (g), fork lengths (mm), and scale samples ("AWL data") were collected daily from 20 randomly selected sockeye salmon smolts. In addition, the lengths of 30 randomly selected sockeye salmon smolts were measured daily. An anesthetic, Tricaine methanesulfonate (MS-222), was administered to the sample smolts for ease in AWL data gathering.

Each year prior to release, a portion of the Crooked Creek Hatchery-reared sockeye salmon fingerling are marked for identification by clipping either the right or left ventral fin. The ventral fins of about two thousand sockeye salmon smolts were examined daily. The numbers of marked fish provided information to determine the hatchery fingerling survival rate and contribution to the total migration.

#### Smolt Population Estimate

The trap efficiency (interception rate) was estimated weekly during the migration period by a simple mark and recapture procedure. This involved placing several hundred smolts into a

holding tank containing a Bismark Brown Y dye solution (1 g dye per 30 liter H<sub>2</sub>O) for 30 minutes. The smolts became gold tinted and were easily distinguished from undyed smolts. The holding tank was equipped with an aeration system that provided a continuous flow of oxygen. The tank was transported approximately 0.7 km upstream by riverboat and the smolts were distributed evenly across the river. The numbers of dyed smolts recovered in the traps were used to estimate the percentage of all smolts intercepted (trap efficiency). Rawson (1982) discusses the estimation of migrating smolt populations using the above technique. The population estimate is calculated according to the formula:

$$\hat{N} = (nD/d) [1 + (D-d)/(Dd)]$$

Where:  $\hat{N}$  = estimated total population  
 D = number of fish dyed  
 d = number of dyed fish recapture  
 n = number of unmarked smolts caught in traps

The estimated variance of  $\hat{N}$  may be calculated from the formula [Rawson (1982)]:

$$\text{Var } (\hat{N}) = n (n + d) D (D + d) / d^3.$$

Using this quantity, a 95% confidence interval for  $\hat{N}$  may be determined under the assumption of a normal distribution for  $\hat{N}$ .

The percent of the smolt migration composed of age 1.0 and 2.0 smolts was estimated for each weekly period using scales obtained from a sample of the daily catch. This percentage was then applied to the estimated total migration for the same period to obtain estimates of the number of migrating smolts in each age class. The formula used to obtain these estimates and their variances is discussed in Appendix C of Flagg et al. (1984).

### Hatchery Contribution and Survival Rate

In June 1982, 15.95 million sockeye fingerling from the Crooked Creek Hatchery were released into Bear Creek and Glacier Flats Creek, tributaries of Tustumena Lake. Of these, 459,000 were marked by ventral fin clips (Bear Creek-LV; Glacier Flats Creek-RV). Age 1.0 sockeye salmon smolts from the 1982 fingerling release migrated from Tustumena Lake during 1983, and age 2.0 smolts from the same release migrated during 1984.

In June 1983, 16.9 million hatchery-reared sockeye salmon fingerling were released from the Crooked Creek Hatchery into Bear Creek and Glacier Flats Creek. A total of 420,000 of those fingerling were fin clipped. The survivors of these fingerling migrated out of the lake as age 1.0 smolts in 1984. Age 2.0 smolts from this release will migrate in 1985.

During 1984 the sockeye salmon smolts caught in the traps were inspected for missing ventral fins. The number of marked fish recovered was then used to estimate the hatchery fry survival and contribution to the total smolt migration. The formula used for calculating the variance of this estimate was derived by Reed (1981), and it is available in an HP-97 program from the FRED Biometrics section in Anchorage (Howe 1981).

### Physical Parameters

Water velocity in meters per second was measured with a Teledyne Gurley meter. Velocity measurements were taken 2 m in front of each trap to avoid any turbulence created by the traps.

Discharge was estimated by this method on 20 June to correlate with trends in the smolt migration. Total discharge was also measured periodically throughout the study using a U.S.

Geological Survey water gauge located at the Kasilof River - Sterling Highway Bridge.

Water temperatures (°C) were recorded daily at the smolt site to assess any relationship between smolt migration and water temperature.

## RESULTS

### Smolt Enumeration and Sampling

Between 11 May and 10 July a total of 1,243,000 sockeye salmon smolts were captured in the four traps (Table 1). The peak of migration occurred during late May (20 May-31 May) when 925,000 smolts (74.4% of the total catch) were caught. The highest daily catch occurred on 28 May when 189,900 smolts were captured (Figure 2).

Scales were collected and weights and lengths of 1,192 sockeye salmon smolts were measured. The mean lengths of age 1.0 and age 2.0 smolts were 72.7 mm and 84.5 mm, respectively. The mean weights of age 1.0 and age 2.0 smolts were 3.3 g and 5.2 g, respectively (Table 2).

During 1984, 80% of the smolts were age 1.0 and 20% age 2.0. The peak migration of age 1.0 and age 2.0 smolts occurred during the same time period (20 May-31 May). Age 2.0 smolts comprised 28% of migrating smolt during the first three weeks of the migration, declined to 10% during the middle three weeks, and then increased again to 26% during the last two weeks of the migration (Table 3).

In addition to sockeye salmon, 9 other fish species, including three other Pacific salmon species, were captured in the Kasilof River traps (Table 4). Of these, chinook salmon, *O. tshawytscha*, were most abundant; 5,400 were caught, of which 3,400 were smolts.

Table 1. Daily catches of sockeye salmon smolts by trap, Kasilof River, 1984.

Date	Trap number				Daily
	2	3	4	5	
05/12				61	61
05/13				45	45
05/14				141	141
05/15		Traps 3 and 4 installed		156	156
05/16	Trap installed	4,602	1,110	327	6,039
05/17	6	11,689	3,133	1,041	15,869
05/18	4	9,389	1,953	447	11,793
05/19	13	27,986	4,308	903	33,210
05/20	62	46,867	7,106	3,815	57,850
05/21	74	72,012	10,984	2,445	85,515
05/22	28	16,282	3,733	1,168	21,211
05/23	79	116,049	16,878	7,306	140,312
05/24	130	66,229	11,036	2,529	79,924
05/25	159	34,573	5,954	3,838	44,524
05/26	115	68,489	10,581	7,205	86,390
05/27	37	54,330	8,845	3,702	66,914
05/28	61	157,449	20,816	11,582	189,908
05/29	63	62,987	14,803	2,765	80,618
05/30	39	10,383	2,551	1,466	14,439
05/31	17	50,257	3,624	3,074	56,972
06/01	44	26,610	3,002	498	30,154
06/02	47	27,220	3,445	181	30,893
06/03	17	14,711	2,251	150	17,129
06/04	8	8,394	2,264	163	10,829
06/05	46	7,433	2,449	84	10,012
06/06	16	4,601	1,379	70	6,066
06/07	20	4,039	472	36	4,567
06/08	20	1,986	535	30	2,571
06/09	16	1,518	347	47	1,928
06/10	68	5,903	1,133	154	7,258
06/11	32	3,557	636	60	4,285
06/12	33	2,647	576	115	3,371
06/13	37	2,301	563	66	2,967
06/14	257	7,122	2,108	144	9,631
06/15	75	3,523	974	125	4,697
06/16	51	1,309	210	49	1,619
06/17	34	1,165	402	27	1,628
06/18	105	2,421	629	158	3,313
06/19	201	4,767	1,275	255	6,498
06/20	176	7,375	1,502	117	9,170
06/21	179	13,245	1,888	140	15,452
06/22	272	19,059	2,028	133	21,492

-continued-

Table 1 continued. Daily catches of sockeye salmon smolts by trap,  
Kasilof River, 1984.

Date	Trap number				Daily
	2	3	4	5	
06/23	96	8,009	963	137	9,205
06/24	66	7,084	667	83	7,900
06/25	62	2,321	600	61	3,044
06/26	87	1,722	429	33	2,271
06/27	133	2,824	616	70	3,643
06/28	134	1,238	499	52	1,923
06/29	191	3,469	900	80	4,640
06/30	251	920	556	46	1,773
07/01	179	2,091	415	71	2,756
07/02	79	344	149	12	584
07/03	109	755	79	26	969
07/04	189	881	88	41	1,199
07/05	112	787	348	85	1,332
07/06	110	724	179	38	1,051
07/07	137	849	110	104	1,200
07/08	251	700	228	41	1,220
07/09	94	540	316	N.A.	950
07/10	54	N.A.	N.A.	N.A.	54
Trap totals	4,975	1,015,737	164,625	57,798	1,243,135
% Caught in each trap	0.4%	81.7%	13.2%	4.7%	

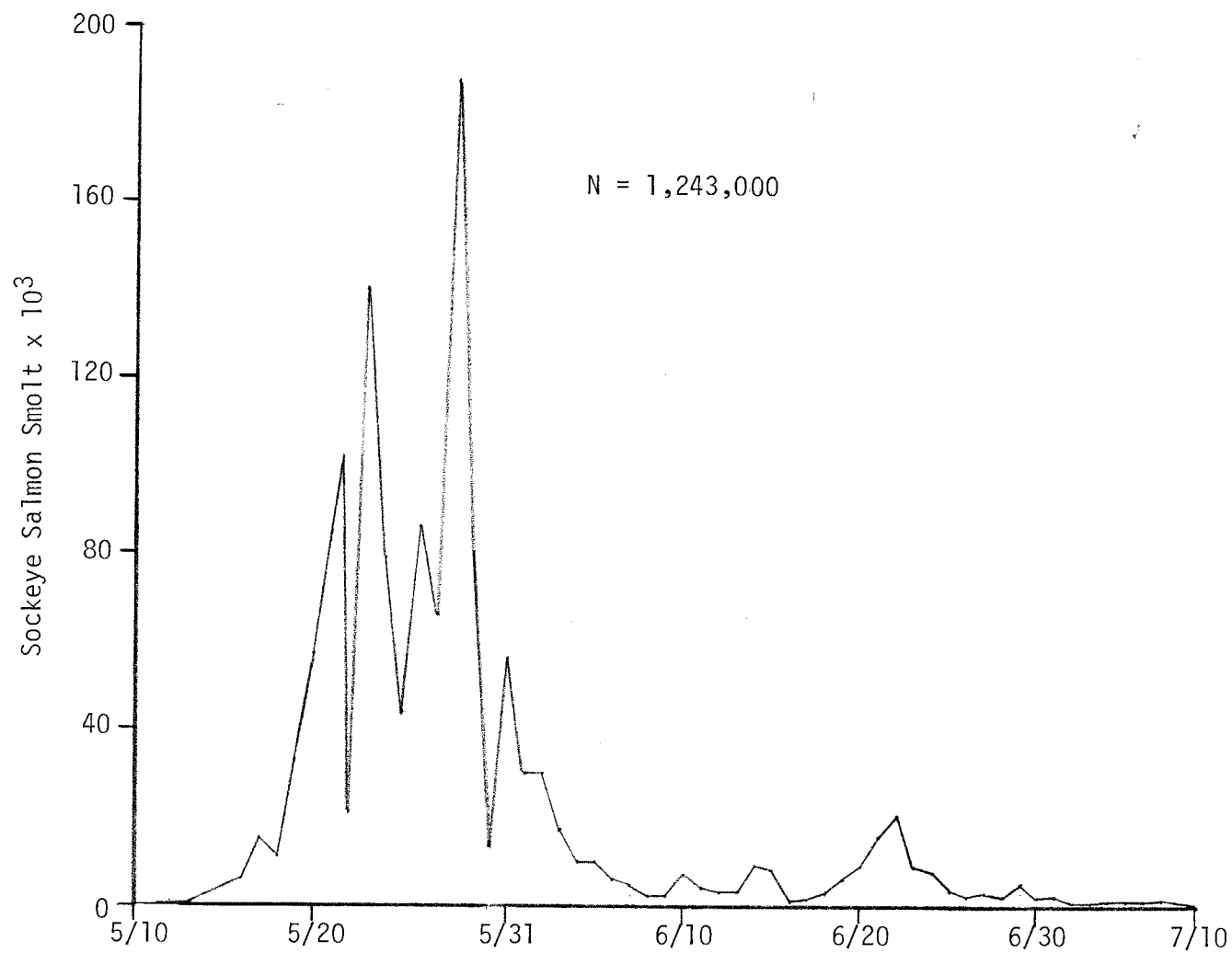


Figure 2. Daily catch of sockeye salmon smolt in the Kasilof River 11 May-10 July 1984. Total catch for the period was 1,243,000.

Table 2. Mean lengths, weights, and standard deviations (S.D.) of sockeye salmon smolts, Kasilof River, 1984.

Sample period	Dates	Mean length (mm)	S.D.	Mean weight (g)	S.D.	Sample size
<u>Age 1.0</u>						
1	5/17-5/19	73.4	4.05	3.1	0.55	51
2	5/20-5/26	72.0	4.15	3.4	0.58	130
3	5/27-6/02	70.9	3.49	3.0	0.51	147
4	6/03-6/09	71.0	3.88	3.0	0.52	165
5	6/10-6/16	72.1	3.68	3.2	0.54	163
6	6/17-6/23	72.6	3.63	3.3	0.54	157
7	6/24-6/30	74.3	2.18	3.8	0.45	76
8	7/01-7/08	75.9	2.64	3.9	0.41	116
Season		72.7 <sup>1</sup>		3.3 <sup>1</sup>		1,005
<u>Age 2.0</u>						
1	5/17-5/19	85.5	4.61	5.0	0.87	25
2	5/20-5/26	84.5	4.91	5.4	0.90	43
3	5/27-6/02	85.9	3.98	4.9	0.65	28
4	6/03-6/09	86.3	5.44	5.3	0.95	10
5	6/10-6/16	85.8	4.78	5.3	1.01	12
6	6/17-6/23	82.5	4.06	5.0	0.83	18
7	6/24-6/30	82.8	4.08	5.3	0.72	18
8	7/01-7/08	83.9	3.72	5.3	0.76	33
Season		84.5 <sup>1</sup>		5.2 <sup>1</sup>		187

<sup>1</sup>Weighted by total population estimate of respective age smolts.

Table 3. Summary of age composition estimates, Kasilof River, 1984.

Sample period	Sample size	Sample composition		Estimated percent Age 1	95% Confidence interval for percent age 1*
		Age 1	Age 2		
5/11-5/19	75	50	25	66.7	[54.7, 76.9]
5/20-5/26	174	130	44	74.7	[67.5, 80.8]
5/27-6/02	175	147	28	84.0	[77.5, 88.9]
6/03-6/09	175	165	10	94.3	[89.4, 97.1]
6/10-6/16	161	142	9	88.2	[81.9, 92.6]
6/17-6/23	175	157	18	89.7	[84.0, 93.6]
6/24-6/30	100	81	19	81.0	[71.7, 87.9]
7/01-7/08	151	117	34	77.5	[69.8, 83.7]

\*95% confidence intervals calculated from equations (1.26) and (1.27) of Fleiss (1981).

Table 4. List of species captured by fan-traps in the Kasilof River, 1980 through 1984<sup>1</sup>.

Common name	Scientific name	Year				
		1980	1981	1982	1983	1984
Sockeye salmon	<i>Oncorhynchus nerka</i> (Walbaum)	64,535	155,531	418,592	529,226	1,243,135
Chinook salmon (fry)	<i>Oncorhynchus tshawytscha</i> (Walbaum)	335	1,413	677	1,513	2,035
Chinook salmon (smolt)	<i>Oncorhynchus tshawytscha</i> (Walbaum)	2,933	8,367	2,297	1,586	3,412
Coho salmon	<i>Oncorhynchus kisutch</i> (Walbaum)	45	107	828	684	2,416
Pink salmon	<i>Oncorhynchus gorbuscha</i> (Walbaum)	436	19,508	80	54,190	83
Dolly Varden	<i>Salvelinus malma</i> (Walbaum)	90	132	115	119	278
Rainbow trout	<i>Salmo gairdneri</i> (Richardson)	1	0	0	0	0
Round whitefish	<i>Prosopium cylindraceum</i> (Phallas)	3	0	1	0	1
Eulachon	<i>Thaleichthys pacificus</i> (Richardson)	0	9	3	36,662	6
Slimy sculpin	<i>Cottus cognatus</i> (Richardson)	681	4,929	2,580	1,064	5,384
Threespine stickleback	<i>Gasterosteus aculeatus</i> (Linnaeus)	181	2,994	1,684	4,061	29

<sup>1</sup>Note: These numbers are not necessarily comparable from year to year since the trap efficiencies varied, both within and between years.

### Smolt Population Estimate

Seven trap-efficiency tests were conducted during the migration. The proportion of marked smolts recovered in the traps was not consistent over the duration of the run as verified by a chi-square test ( $\chi^2 = 43.17$ , d.f. 6). For estimating the magnitude of the smolt migration, the seven trap-efficiency tests were divided into three groups (Figure 3, Table 5).

Trap efficiency was highest during the first period (11 May-24 June) with five dye tests ( $\chi^2 = 5.55$ , d.f. 4) giving an average 9.2% recovery rate. This high rate was due to low water discharge that resulted in a greater percentage of the total volume passing through the smolt traps. An estimated 13.3 million sockeye salmon smolts migrated during the first period (Table 6).

During the second period (26 June-30 June) a trap efficiency estimate of 4.6% was obtained from a single mark and recapture test. During this period an estimated 390,000 smolts migrated. During the third period (1 July-9 July) a trap efficiency estimate of 2.2% was obtained from a single mark and recapture test. An estimated 560,000 smolts migrated during this final time period.

The total sockeye salmon smolt migration from Tustumena Lake in 1984 was estimated to be 14.3 million ( $\pm 2.9$  million).

The age composition of the smolt run was estimated by weekly periods according to the method discussed in Flagg, Owecke, and Waite (1984). The results (Table 7) indicate that the peak migration of age 2.0 smolts occurred during the same time period (late May) as age 1.0 smolts (Figure 4). Overall, the run was estimated to be composed of 11.4 million age 1.0 smolts and 2.9 million age 2.0 smolts.

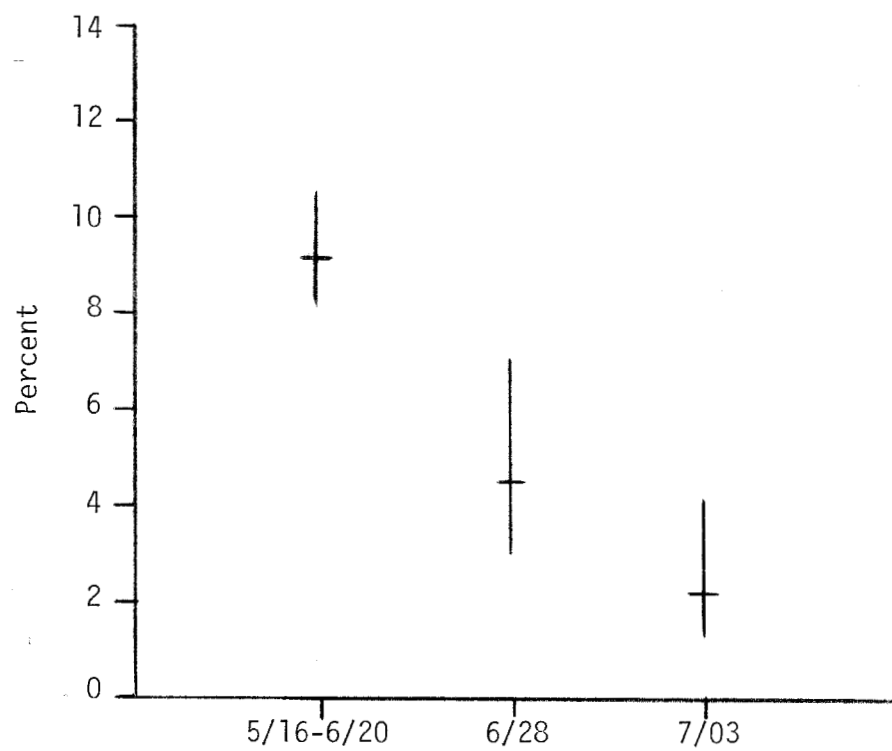


Figure 3. Results of the Kasilof River dye tests, 1984. The horizontal lines indicate the estimated trap efficiencies. The vertical lines represent 95% Confidence Intervals for the estimated trap efficiencies.

Table 5. Summary of dye mark recovery results, Kasilof River, 1984.

Date	Dyed fish released	Dyed fish recovered	Percent dyed fish recovered	95% Confidence interval*
<u>Period 1</u>				
5/16	500	42	8.4	[6.2, 11.3]
5/26	500	56	11.2	[8.6, 14.4]
6/02	500	36	7.2	[5.2, 9.9]
6/13	500	46	9.2	[6.9, 12.2]
6/20	500	50	10.0	[7.6, 13.1]
Total	2,500	230	9.2	[8.1, 10.4]
<u>Period 2</u>				
6/28	500	23	4.6	[3.0, 6.9]
<u>Period 3</u>				
7/03	500	11	2.2	[1.2, 4.0]

\*Based on equations (1.26) and (1.27) of Fleiss (1981).

Table 6. Summary of smolt outmigration estimates, Kasilof River, 1984.

Period	Dyed fish released (D)	Dyed fish recovered (d)	Unmarked fish caught (n)	Outmigration estimated ( $\bar{n}$ ) (thousands)
05/11-06/24	2,500	229	1,214,526	13,312 [11,675-14,949]
06/25-06/30	500	23	17,294	392 [ 241- 542]
07/01-07/09	500	11	11,261	557 [ 257- 854]
Overall				14,261 [12,588-15,929]

Table 7. Summary of the weekly estimates of smolt migration by age class, Kasilof River, 1984. All quantities are in thousands of fish.

Sample period	Age 1		Age 2	
	Migration estimate	95% Confidence interval <sup>1</sup>	Migration estimate	95% Confidence interval <sup>1</sup>
5/11-5/19	492.1	[ 393.2- 591.0]	245.7	[ 161.6- 329.8]
5/20-5/26	4222.6	[3,591.1- 4,854.1]	1430.1	[1,026.3-1,833.9]
5/27-6/02	4326.3	[3,728.7- 4,923.9]	824.0	[ 527.4-1,120.6]
6/03-6/09	548.0	[ 477.9- 618.1]	33.2	[ 12.8- 53.6]
6/10-6/16	327.0	[ 282.9- 371.1]	43.8	[ 24.6- 63.0]
6/17-6/23	656.0	[ 569.2- 742.8)	76.4	[ 42.3- 110.5]
6/24-6/30	387.3	[ 204.6- 570.0]	90.8	[ 29.8- 151.8]
7/01-7/09	430.5	[ 196.2- 664.8]	125.0	[ 47.6- 202.4]
Overall	11,389.8	[9,443.8-13,335.8]	2,869.0	[1,872.4-3,865.6]

<sup>1</sup>The confidence intervals were calculated as described by Flagg et al. (1983).

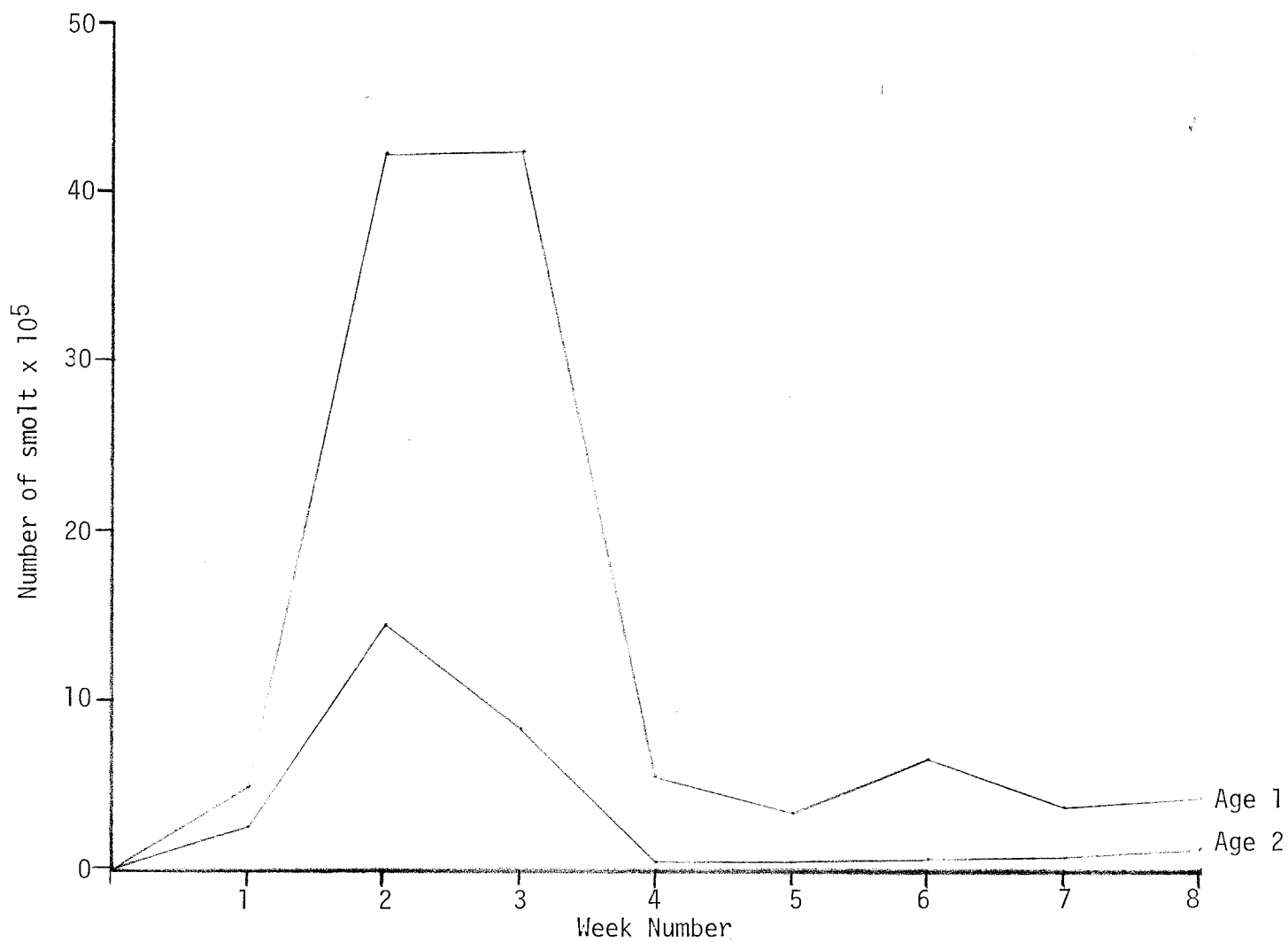


Figure 4. Estimated migration patterns of age 1.0 and 2.0 sockeye salmon smolt, by week, Kasilof River, 1984.

The total estimated biomass of sockeye salmon smolts migrating from Tustumena Lake was 51,600 kg. This estimate was calculated by multiplying the weekly mean weights of age 1.0 and 2.0 smolts by the weekly estimated migration and then summing the results (Table 8).

#### Hatchery Contribution and Survival Rate

A total of 68,539 sockeye salmon smolts or 5.5% of the smolts captured were observed for clipped ventral fins. There were 378 fin-clipped smolts recovered; 325 were age 1.0 and 53 were age 2.0. Of the age 1.0 fin-clipped smolts, 165 were RV (right ventral) from Bear Creek stock and 160 were LV (left ventral) from Glacier Flats Creek stock. Of the age 2.0 smolts, 29 were RV and 24 were LV.

Reed's (1981) formulas were used to calculate the survival rate, and hatchery contribution to the 1983 sockeye smolt migration. Survival to age 1.0 of marked hatchery sockeye fingerling released into Tustumena Lake in 1983 was estimated at 16.3%. This is a preliminary survival rate, since age 2.0 smolts from the 1983 release will not migrate until 1985. Survival of 1982-released fingerling to age 2.0 smolt was estimated at 2.5%. Total survival rate of 1982-released fingerling to smolt was estimated to be 12.3% (10% to age 1.0, 2.3% to age 2.0).

The number of hatchery-produced smolts in the 1984 Kasilof River sockeye salmon migration for each age class was estimated by multiplying the above survival rate estimates by the total number of fingerling released in the respective year. The 1984 migration was comprised of an estimated 3.15 million hatchery-produced fish (Table 9). Table 10 is a summary of the estimated contribution of hatchery-produced sockeye salmon to the Kasilof smolt migration from 1980-1984. The survival and hatchery-contribution values reported were not adjusted for differential

Table 8. Estimated sockeye salmon smolt biomass migrating from Tustumena Lake, 1984.

Sample period	Mean weight (g)		Estimated number migrants		Estimated biomass (Kg)	
	Age 1.0	Age 2.0	Age 1.0	Age 2.0	Age 1.0	Age 2.0
5/11-5/19	3.2	4.9	492,100	245,700	1,574.7	1,203.9
5/20-5/26	3.4	5.3	4,222,600	1,430,100	14,356.8	7,579.5
5/27-6/02	3.0	4.9	4,326,300	824,000	12,978.9	4,037.6
6/03-6/09	3.0	5.3	548,000	33,200	1,644.0	176.0
6/10-6/16	3.2	5.3	327,000	43,800	1,046.4	232.1
6/17-6/23	3.3	5.0	656,000	76,400	2,164.8	377.0
6/24-6/30	3.6	5.3	387,300	90,800	1,394.3	481.2
7/01-7/09	3.9	5.3	430,500	125,000	1,678.9	662.5
Season	3.3	5.2	11,389,800	2,869,000	36,838.8	14,749.8

Total estimated biomass =  $51.6 \times 10^3$  Kg

$51.6 \times 10^3$  Kg/29,107 ha = 1.77 Kg/ha

Mean water temperatures for May, June, and July were 9.3°C (48.7°F), 12.6°C (54.7°F), and 14.1°C (57.4°F), respectively.

Table 9. Summary of the estimated contribution of hatchery-produced sockeye salmon to the Kasilof River 1984 smolt migration.

Brood year	Release year	Smolt age	Estimated percent survival	Total release	Estimated hatchery contribution <sup>1</sup>
1981	1982	2	2.47 <sup>2</sup>	15.95 x 10 <sup>6</sup>	393,960
1982	1983	1	16.28 <sup>3</sup>	16.93 x 10 <sup>6</sup>	2,757,721

<sup>1</sup>Survival rate and variance of 95% confidence interval calculated from Reed's (1981) formulas; refer to Flagg (1983).

<sup>2</sup>Does not include survival to age 1.0 smolt in 1983.

<sup>3</sup>Does not include survival to age 2.0 smolt in 1985.

Table 10. Summary of the estimated contribution of hatchery-produced sockeye salmon to the Kasilof River smolt migration, 1980-1984.

Brood year	Release year	Total release	Estimated survival %			Estimated hatchery contribution <sup>1</sup>	
			Age 1	Age 2	Total	Number	Percent
1978	1979	7.76x10 <sup>6</sup>	.31	.15	0.46	37,500	0.46
1979	1980	5.20x10 <sup>6</sup>	5.52	0.31	5.83	303,000	13.10
1980	1981	8.78x10 <sup>6</sup>	9.98	2.34	12.32	1,081,372	21.00
1981	1982	15.95x10 <sup>6</sup>	11.59	2.47	14.99	2,230,846	23.00
1982	1983	16.93x10 <sup>6</sup>	16.28	--	16.28 <sup>2</sup>	2,757,721	24.21 <sup>2</sup>

<sup>1</sup>Hatchery contribution based on total brood year production.

<sup>2</sup>Age 2.0 smolts will not migrate until 1985, and therefore are not included in these figures.

mortalities that may have resulted from ventral fin removal. A review of the potential impact from differential mortality and fin regeneration appears in the discussion.

### Physical Parameters

#### Kasilof River Discharge:

During 1984, the discharge in the Kasilof River ranged from 17.7 m<sup>3</sup>/s on 9 May to 79.7 m<sup>3</sup>/s on 3 July. The overall discharge was above the long-term average (19.0 m<sup>3</sup>/s - May, 41.3 m<sup>3</sup>/s - June) reported by Scully (1978). Discharge readings taken during 1984 at the U.S.G.S. gauge on the Kasilof River - Sterling Highway Bridge and those taken downstream at the smolt-sampling site appear in Appendix Table 2.

The highest smolt catches were consistently made in the center of the river (Trap 3) where the greatest discharge occurred. On 20 June, when discharge measurements were taken at each trap location, Trap 3 accounted for 80.4% of the smolt catch (Figure 5). Trap 3 accounted for 81.7% of the smolt catch over the entire migration.

#### Water Temperature:

Occuring on four different days during late May, the lowest water temperature recorded during the smolt migration was 7.8°C (46°F). The highest temperature of 15°C (59°F) occurred several days during late June and early July. The mean water temperatures for May, June, and July were 9.3°C (48.7°F), 12.6°C (54.7°F) and 14.1°C (57.4°F), respectively.

During the early part of the migration, water temperatures fluctuated as the number of migrating smolts increased to a peak in late May. After the peak of migration (28 May), the numbers of smolts caught declined while the water temperature gradually increased (Figure 6).

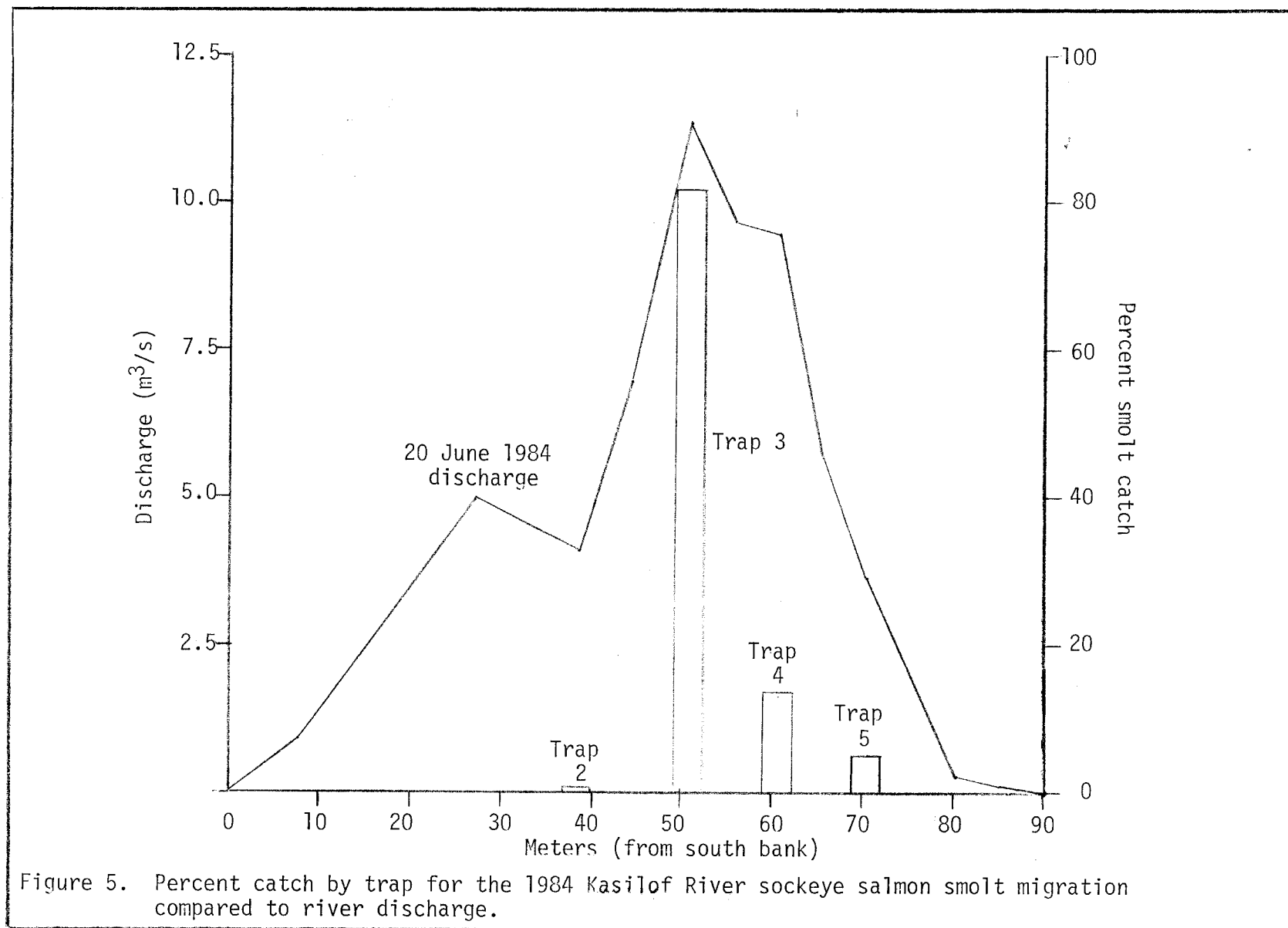


Figure 5. Percent catch by trap for the 1984 Kasilof River sockeye salmon smolt migration compared to river discharge.

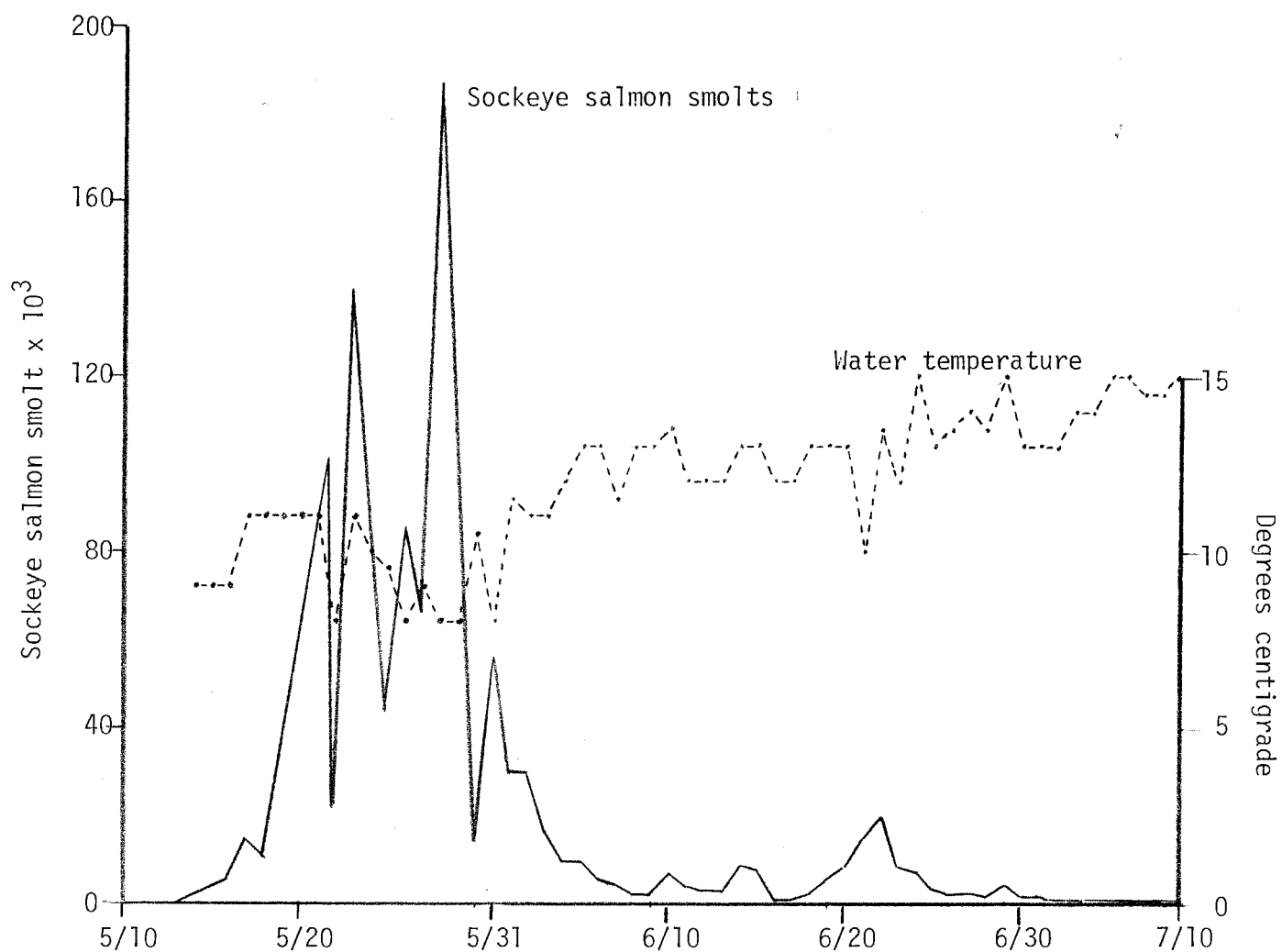


Figure 6. Daily catch of sockeye salmon smolts and average daily water temperature (C), Kasilof River, 1984.

## DISCUSSION

Five years of smolt enumeration have been completed on the Kasilof River (1980-1984). For the fifth consecutive year, our estimates indicate that total sockeye salmon smolt production, hatchery contribution by brood year, and survival of hatchery-released fingerling to smolt have increased over previously obtained values. We have observed no significant change in the condition of sockeye salmon smolts as measured by mean length or weight, nor have we seen any major changes in age composition (Figures 7, 8, 9; Appendix Table 3).

We have compared the condition of hatchery smolts, as identified by fin clips, with wild smolts. Mean lengths and weights of age 1.0 and age 2.0 hatchery sockeye salmon smolts from the Kasilof River 1984 (Table 11) compare favorably to wild smolts (Table 2). The age composition of hatchery smolts (87.5% age 1.0) and wild smolts (80.0% age 1.0) migrating in 1984 differed, however not dramatically. This difference could be due to the fact that all hatchery fry enter the lake in June, while wild fry input occurs over a broader range of time. Wild fry that enter the lake in July or early August would probably not have as good a chance to obtain the growth required to smolt at age 1.0 as fry (wild or hatchery) entering the lake in June.

The 14.3 million sockeye salmon smolt estimate for Tustumena Lake in 1984 is the highest observed since smolt enumeration began in 1980. Thorne (1984) estimated a rearing population of 25.5 million sockeye salmon fry in Tustumena Lake in the fall of 1983. This indicates an overwinter survival value of 56%, which is close to Foerster's (1968) estimated survival value (60%) for fall fry-to-yearling sockeye salmon migrants in Cultus Lake. It is also close to our overwinter survival estimates for 1980-1981

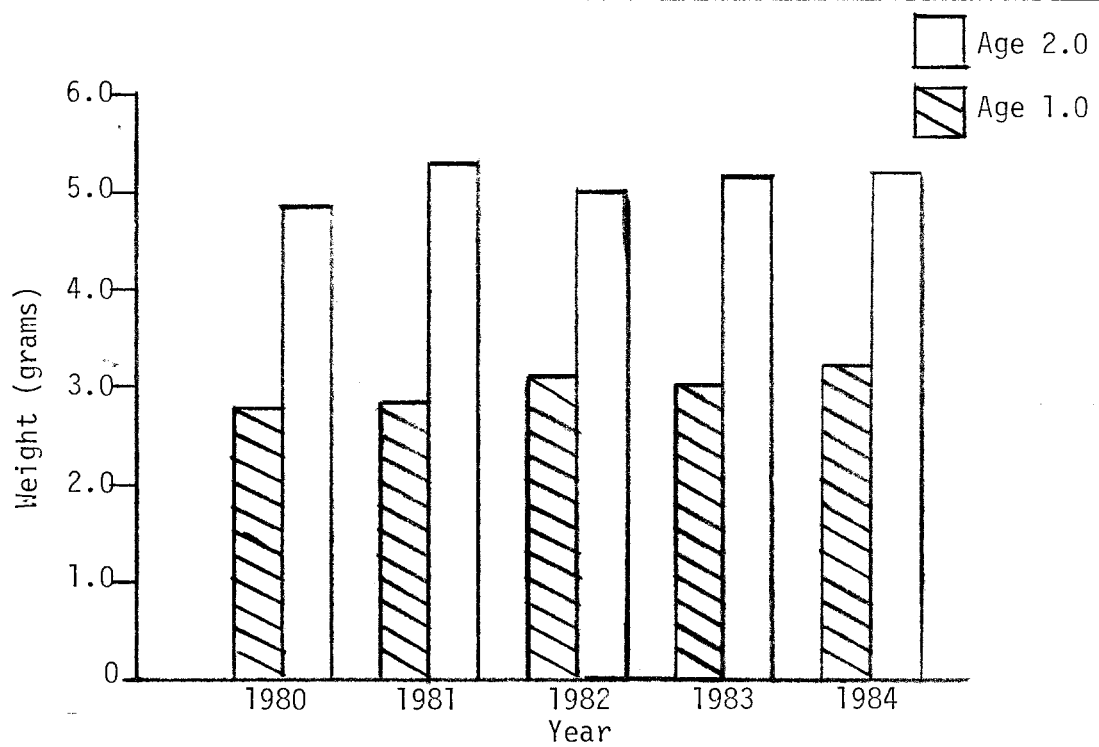


Figure 7. Mean weight (g) of age 1.0 and age 2.0 sockeye salmon smolts in Kasilof River sampling years 1980-1984.

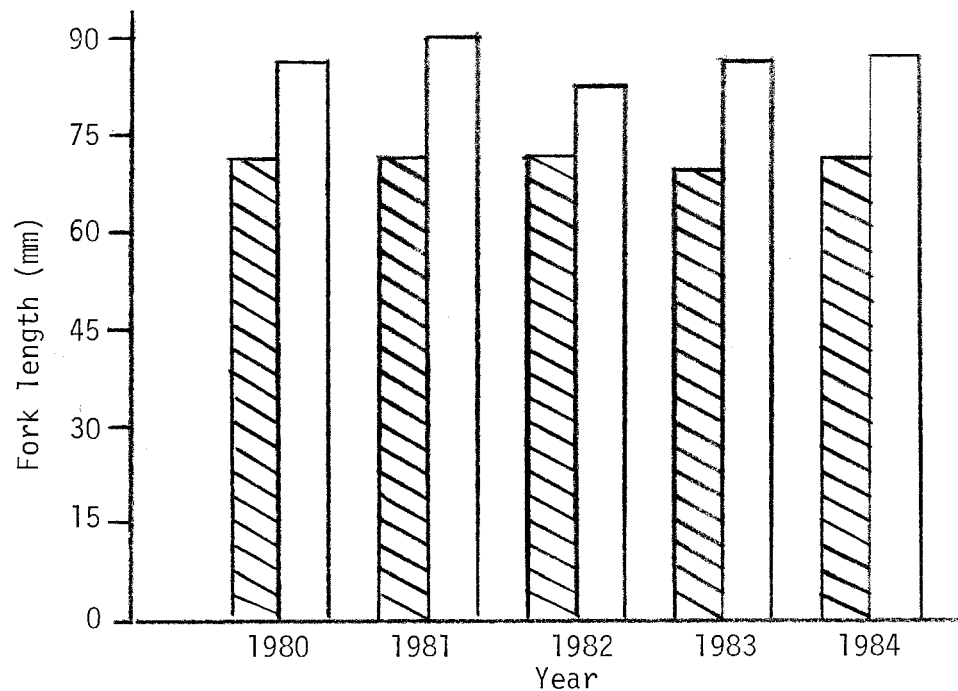


Figure 8. Mean fork length of age 1.0 and age 2.0 sockeye salmon smolts in the Kasilof River, 1980-1984

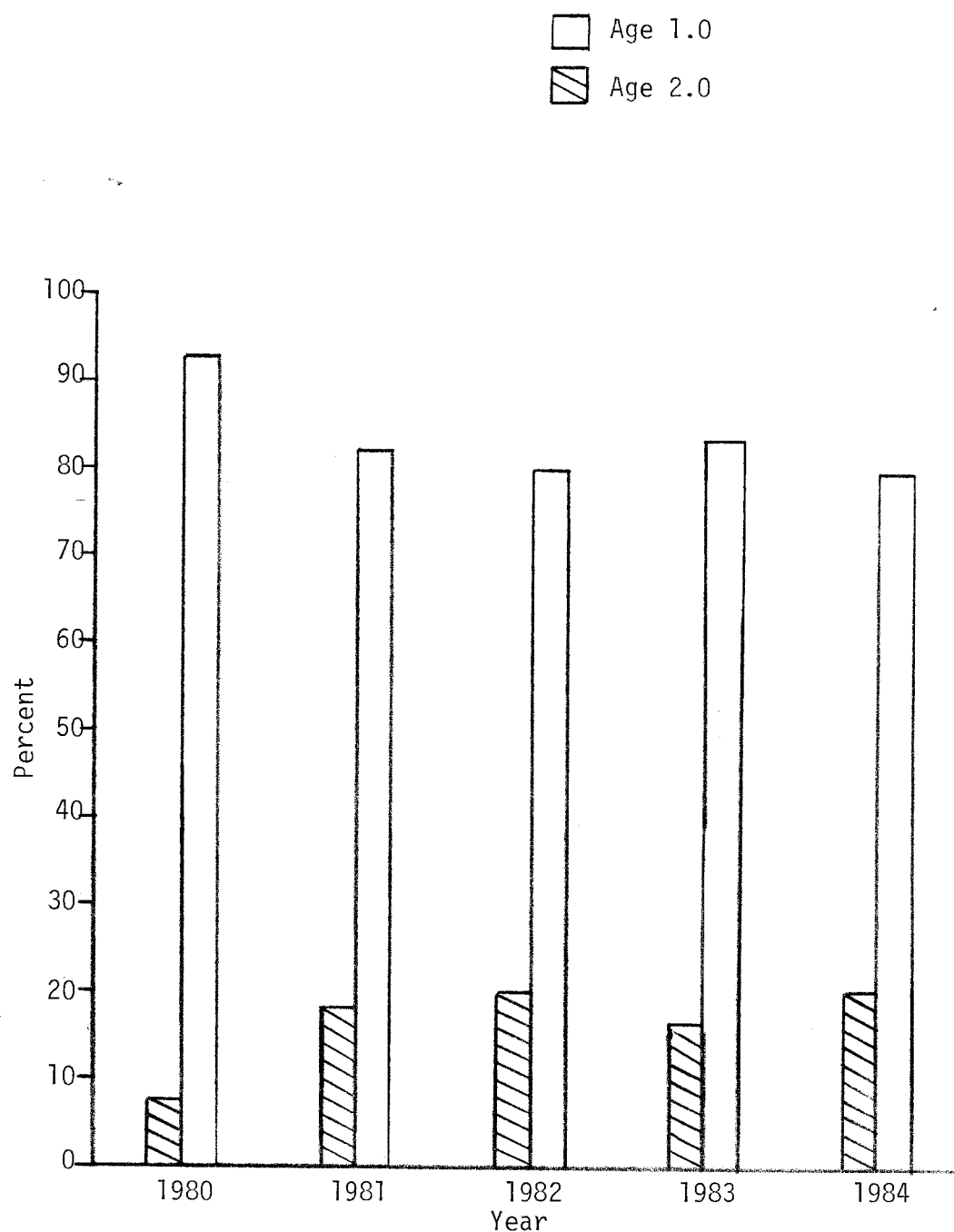


Figure 9. Percent age class of age 1.0 and age 2.0 sockeye salmon smolts in the Kasilof River, 1980-1984.

Table 11. Mean lengths, weights, and standard deviations (S.D.) of finclipped sockeye salmon smolts, Kasilof River, 1984.

Sample period	Dates	Mean length (mm)	S.D.	Mean weight (g)	S.D.	Sample size
<u>Age 1.0</u>						
1	5/17-5/19	73.7	3.95	3.5	0.57	29
2	5/20-5/26	72.2	3.51	3.4	0.60	101
3	5/27-6/02	71.5	4.08	3.3	0.51	45
4	6/03-6/09	72.6	4.33	3.2	0.59	61
5	6/10-6/16	73.4	4.32	3.4	0.68	52
6	6/17-6/23	74.2	3.04	3.5	0.39	18
7	6/24-6/30	73.7	2.98	3.8	0.47	10
8	7/01-7/08	76.3	1.50	4.3	0.42	4
Season		72.7 <sup>1</sup>		3.4 <sup>1</sup>		320
<hr/>						
<u>Age 2.0</u>						
1	5/17-5/19	84.4	3.32	5.3	0.66	11
2	5/20-5/26	84.4	5.50	5.2	1.01	7
3	5/27-6/02	84.3	5.87	5.1	0.97	8
4	6/03-6/09	84.7	4.04	5.2	0.60	3
5	6/10-6/16	83.7	4.19	4.8	0.84	7
6	6/17-6/23	81.3	3.44	4.7	0.58	6
7	6/24-6/30	88.5	9.19	5.6	0.92	2
8	7/01-7/08	84.4	4.03	5.5	0.72	9
Season		84.3 <sup>1</sup>		5.2 <sup>1</sup>		53

<sup>1</sup>Weighted by total population estimate for each respective age.

(60%) and 1982-1983 (62%) at Tustumena Lake (Flagg 1983; Flagg et al. 1984). An analysis of Babine Lake sockeye data indicates an average fall fry-to-smolt survival value of 53% (McDonald and Hume 1984).

If 10% of the estimated number of smolts return as adults (FRED Division 1979), a total return of approximately 1.4 million sockeye salmon adults is forecasted from the 1984 smolt migration. This estimate is three times (3X) the long-term average estimated adult return for Tustumena Lake and is about 75% higher than the highest return (806,000 in 1980) ever recorded for the Tustumena Lake system (Cross et al. 1983). We expect that the hatchery contribution to this return would be at least 22%.

There is some evidence that the survival rate of fin-clipped fish is less than that of nonclipped fish. Nicola and Cordone (1973) observed a 60% to 70% long-term reduction in survival in rainbow trout after the removal of a ventral fin. Foerster (1968) reported that marking experiments on sockeye salmon at Cultus Lake suggest a 62% differential mortality due to marking and/or absence of excised fins. Boyle (1984) estimated a fin mark loss rate of 40% to 70% in pink salmon that had one ventral fin removed. There is some indication that fin regeneration may cause a substantial loss of marks. Hauser (1984) estimated that after 12 months from the time of ventral fin clipping, 23% of the clipped fins of Kasilof River sockeye salmon fry had regenerated.

If the survival rate of the ventral-fin-clipped sockeye salmon fry released since 1979 is actually less than the survival rate of unmarked fry, then survival values and hatchery contribution to the total smolt migration would be greater than we have reported. If we assumed an average mark-loss rate of 50% (which may be reasonable), then hatchery contribution to the 1984 Kasilof River sockeye salmon smolt migration would be estimated at 6.3 million or 44.2%.

There is no indication that the stocking of hatchery-reared sockeye salmon fingerling in Tustumena Lake is having any short-term adverse effect upon the wild sockeye population or total sockeye production in the lake. All of our data indicate that the stocking of sockeye fingerling has resulted in an increase in total sockeye smolt production from Tustumena Lake without any measurable adverse effect upon the wild population. The mean size of migrating smolts in 1984 was actually larger than those migrating in 1980 when the evaluation program was initiated.

Although analysis of limnological samples (including zooplankton) has not been completed, there is nothing in the preliminary data to suggest that the zooplankters are being overgrazed. Zooplankton numbers have remained fairly consistent over the years of our study, and there has been no gross shift in species composition (Appendix Table 4).

We have attempted to evaluate whether hatchery contribution represents an increase in the population or simply a replacement of wild stock. From all indications it appears that the stocking of sockeye salmon fingerling in Tustumena Lake has resulted in an increase in total production. This production in 1984 exceeded what we might expect the system to produce on its own based on the maximal adult return observed: the 800,000 adult return in 1980 would have required about 8.0 million smolts if we assume a 10% smolt-to-adult return. It is encouraging that the total number of migrating smolts produced by brood year has increased each year along with an increase in hatchery contribution. If this trend continues, we might reasonably conclude that the carrying capacity of the Tustumena Lake system is limited and the stocked sockeye fingerlings are making a contribution to total production without supplanting wild stock. This was the original assumption that led to the initiation of the sockeye salmon enhancement program in 1976.

#### ACKNOWLEDGEMENTS

The authors would like to express appreciation to the Crooked Creek Hatchery staff at Kasilof for the excellent job they did of culturing sockeye salmon used for release during this program and for the cooperation that they have given us. We would also like to thank Michael Owecke (FB I) and Richard Dederick (FT II) for their assistance in conducting field work associated with the smolt project. We also appreciate the editorial and biometric assistance provided by the FRED Division Regional and Headquarters staffs.

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## APPENDIX A

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Appendix Table 1. Tustumena Lake sockeye salmon fry stocking and marking history, 1976-84.

Release year	Glacier Flats Creek			Bear Creek			Total		
	Number fry stocked	Number marked RV	Percent	Number fry stocked	Number marked LV	Percent	Number fry stocked	Number marked	Percent
1976	1,137,784	--	--	--	--	--	1,137,784	--	--
1977	--	--	--	--	--	--	--	--	--
1978	400,000	--	--	--	--	--	400,000	--	--
1979	4,864,193	30,502	.62	2,899,785	36,095	1.24	7,763,978	66,597	.86
1980	2,706,610	32,669	1.20	2,499,232	32,758	1.31	5,205,842	65,427	1.26
1981	4,967,526	198,409	3.99	3,809,045	253,947	6.67	8,776,571	452,356	5.15
1982	8,299,560	210,114	2.53	7,648,602	248,639	3.25	15,948,162	458,753	2.88
1983	9,760,100	201,800	2.07	7,174,800	218,400	3.04	16,934,900	420,200	2.48
1984	9,750,000	202,400AD 202,100RV	2.08 2.07	7,300,000	29,400	0.40	17,050,000	433,900	2.54
		404,500	4.15						

Appendix Table 2. Kasilof River discharge in  
m<sup>3</sup>/s, 1984.

Date	USGS bridge guage	ADF&G
5/09	17.7	---
5/16	20.7	---
5/23	21.1	---
5/26	22.5	---
6/02	25.0	---
6/08	30.6	---
6/14	35.7	---
6/20	42.9	29.6 <sup>1</sup>
6/28	59.0	---
7/03	79.7	---

<sup>1</sup>Digital electronic meter.

Appendix Table 3. Kasilof River smolt migration summary, 1980-1984.

Year	Smolt migration (millions)	Percent age composition		Mean size of age 1.0 smolt		Percent hatchery contribution
		1.0	2.0	Length (mm)	Weight (g)	
1980	1.0	91	9	68	2.7	3
1981	2.3	82	18	70	2.8	13
1982	5.1	80	20	69	2.9	17
1983	8.3	84	16	70	2.9	25
1984	14.2	80	20	73	3.3	22

Appendix Table 4. Seasonal mean densities of macro-zooplankters at two stations in Tustumena Lake, 1980-1984.

Year (May-October)	Station	<i>Cyclops columbianus</i>		<i>Diaptomus pribilofensis</i>		<i>Nauplii</i>		Total
		(No/m <sup>2</sup> )	Percent	(No/m <sup>2</sup> )	Percent	(No/m <sup>2</sup> )	Percent	
1980	B	35,041	56.6	13,237	21.4	13,584	22.0	61,862
1981	B	20,858	24.8	30,078	35.7	33,254	39.5	84,190
1982	B	53,736	76.7	720	1.0	15,597	22.3	70,053
1983	B	37,448	60.7	8,809	14.3	15,450	25.0	61,707
1984	B	34,380	43.0	19,601	25.0	25,535	32.0	79,516
1980	C	34,096	73.2	4,853	10.4	7,600	16.4	46,549
1981	C	24,086	39.8	6,828	11.3	29,624	48.9	60,538
1982	C	43,172	83.1	1,618	3.1	7,125	13.8	51,915
1981	C	49,848	60.6	9,091	11.0	23,380	28.4	82,319
1984	C	26,868	56.0	3,078	6.0	18,060	38.0	48,006

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